US011707759B2

(12) **United States Patent**
Naito et al.

(10) **Patent No.: US 11,707,759 B2**
(45) **Date of Patent: Jul. 25, 2023**

(54) **COATING HEAD, COATING APPARATUS, AND COATING METHOD**

(71) Applicants: **KABUSHIKI KAISHA TOSHIBA**, Tokyo (JP); **TOSHIBA ENERGY SYSTEMS & SOLUTIONS CORPORATION**, Kawasaki (JP)

(72) Inventors: **Katsuyuki Naito**, Bunkyo (JP); **Naomi Shida**, Minato (JP); **Kohei Nara**, Yokohama (JP); **Takahiro Kokubo**, Hiratsuka (JP); **Yutaka Saita**, Yokohama (JP)

(73) Assignees: **KABUSHIKI KAISHA TOSHIBA**, Tokyo (JP); **TOSHIBA ENERGY SYSTEMS & SOLUTIONS CORPORATION**, Kawasaki (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 57 days.

(21) Appl. No.: **17/445,735**

(22) Filed: **Aug. 24, 2021**

(65) **Prior Publication Data**

US 2021/0387222 A1 Dec. 16, 2021

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2020/009946, filed on Mar. 9, 2020.

(51) **Int. Cl.**
B05C 1/08 (2006.01)
B05C 11/10 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***B05C 1/0826*** (2013.01); ***B05C 1/04*** (2013.01); ***B05C 1/0804*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC B05C 1/0826; B05C 11/10; B05C 1/04; B05C 1/0813; B05C 1/0873; B05C 1/0804; B05D 1/28
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2002/0121239 A1* 9/2002 Tonazzi B05C 9/02 118/244
2010/0310778 A1* 12/2010 Shioi B05B 12/122 118/313

FOREIGN PATENT DOCUMENTS

CN 207592089 U 7/2018
CN 108499756 A 9/2018
(Continued)

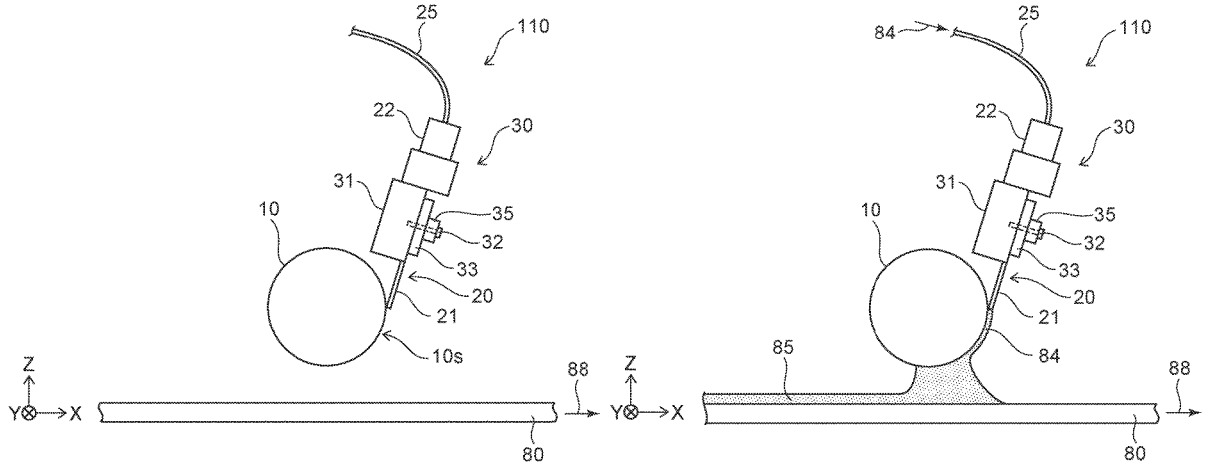
OTHER PUBLICATIONS

International Search Report dated Jun. 9, 2020 in PCT/JP2020/009946 filed on Mar. 9, 2020, 4 pages (with English Translation of Categories of Cited Documents).

Primary Examiner — Laura Edwards
(74) *Attorney, Agent, or Firm* — Oblon, McClelland, Maier & Neustadt, L.L.P.

(57) **ABSTRACT**

According to one embodiment, a coating head includes a coating bar, nozzles, a first member, second members, third members, elastic members, and a position controller. The coating bar faces a coating member. The nozzles supply a liquid toward the coating bar. The first member includes first recesses. A portion of the nozzles is between the first recesses and the third members. The portion of the nozzles and the third members are fixed to the first member by the second members. The elastic members are located in at least first, second, or third positions. The first position is between the third members and the second members. The second position is between the portion of the first recesses and the nozzles. The third position is between the portion of the
(Continued)



nozzles and the third members. The position controller controls a relative position between the coating bar and the nozzles.

20 Claims, 14 Drawing Sheets

(51) **Int. Cl.**
B05C 1/04 (2006.01)
B05D 1/28 (2006.01)

(52) **U.S. Cl.**
CPC ***B05C 1/0813*** (2013.01); ***B05C 1/0873*** (2013.01); ***B05C 11/10*** (2013.01); ***B05D 1/28*** (2013.01)

(58) **Field of Classification Search**
USPC 118/304, 313, 708
See application file for complete search history.

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

JP	09-019657	A	1/1997
JP	2006-256051	A	9/2006
JP	2011-206715	A	10/2011
JP	2016-155113	A	9/2016
JP	2016-155114	A	9/2016
JP	2016-174992	A	10/2016
WO	WO2006095669	*	9/2006

* cited by examiner

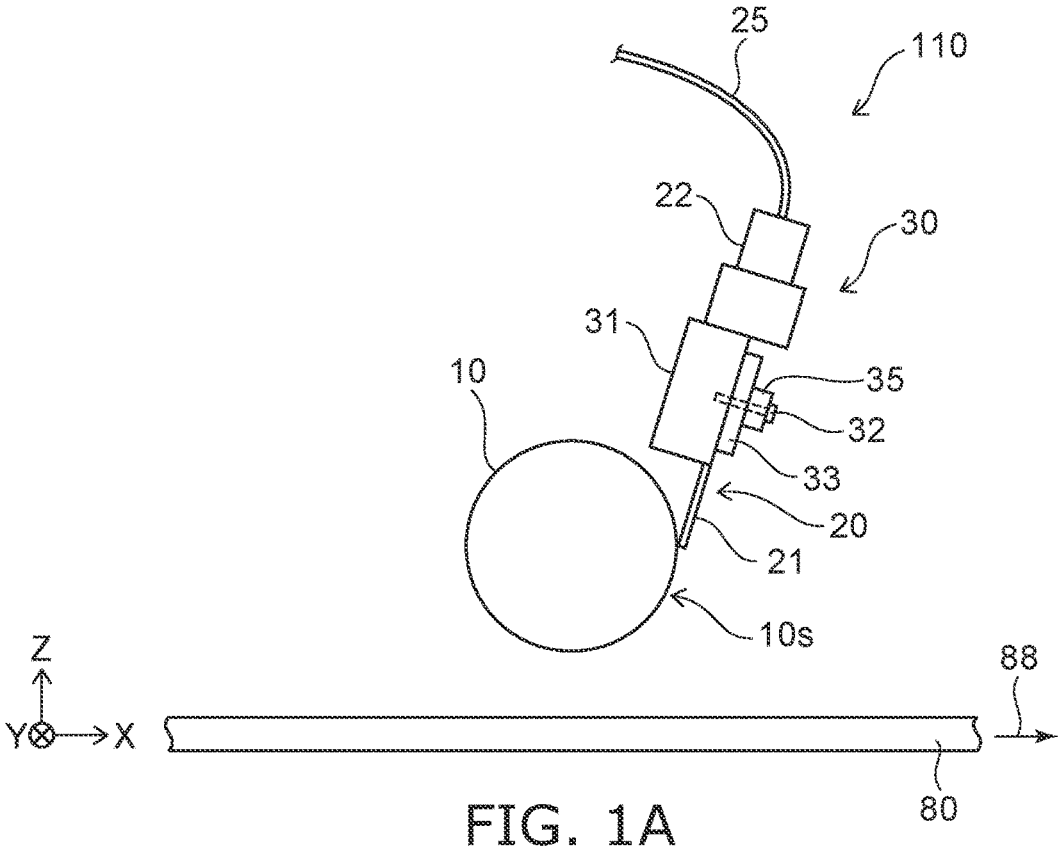

25
110
22
30
31
10
35
32
33
20
21
10s
Z
Y
X
88
80

FIG. 1A

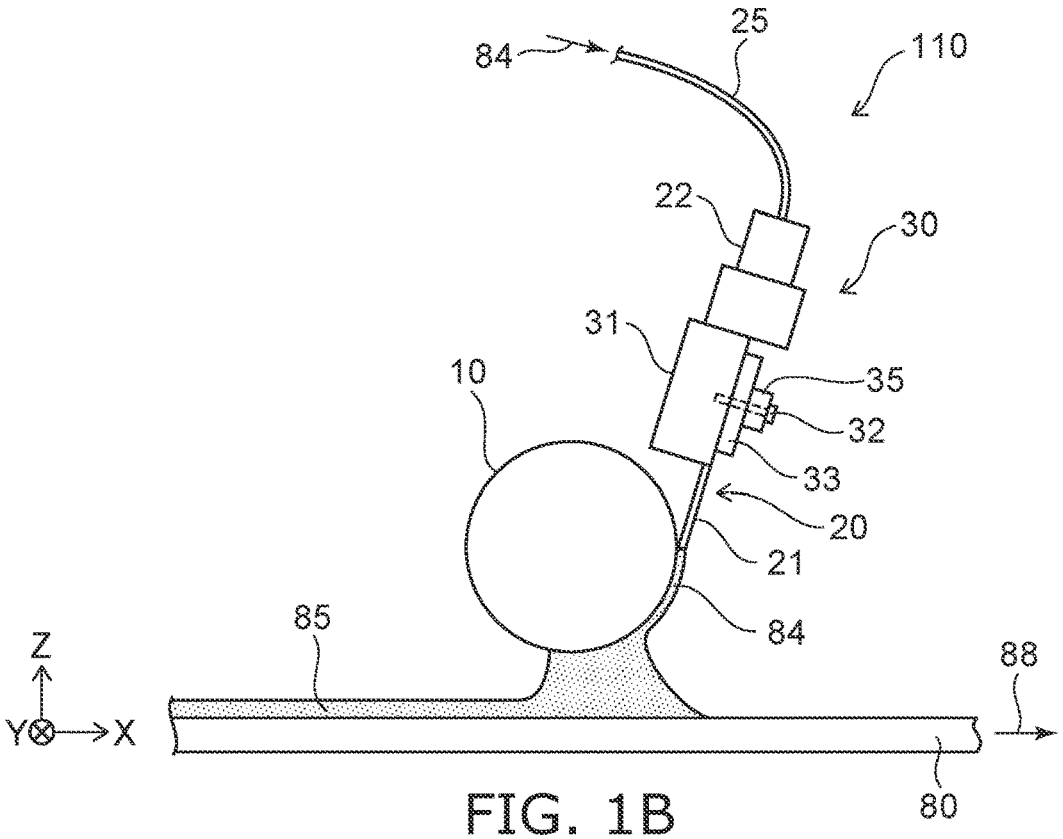

84
25
110
22
30
31
10
35
32
33
20
21
84
85
Z
Y
X
88
80

FIG. 1B

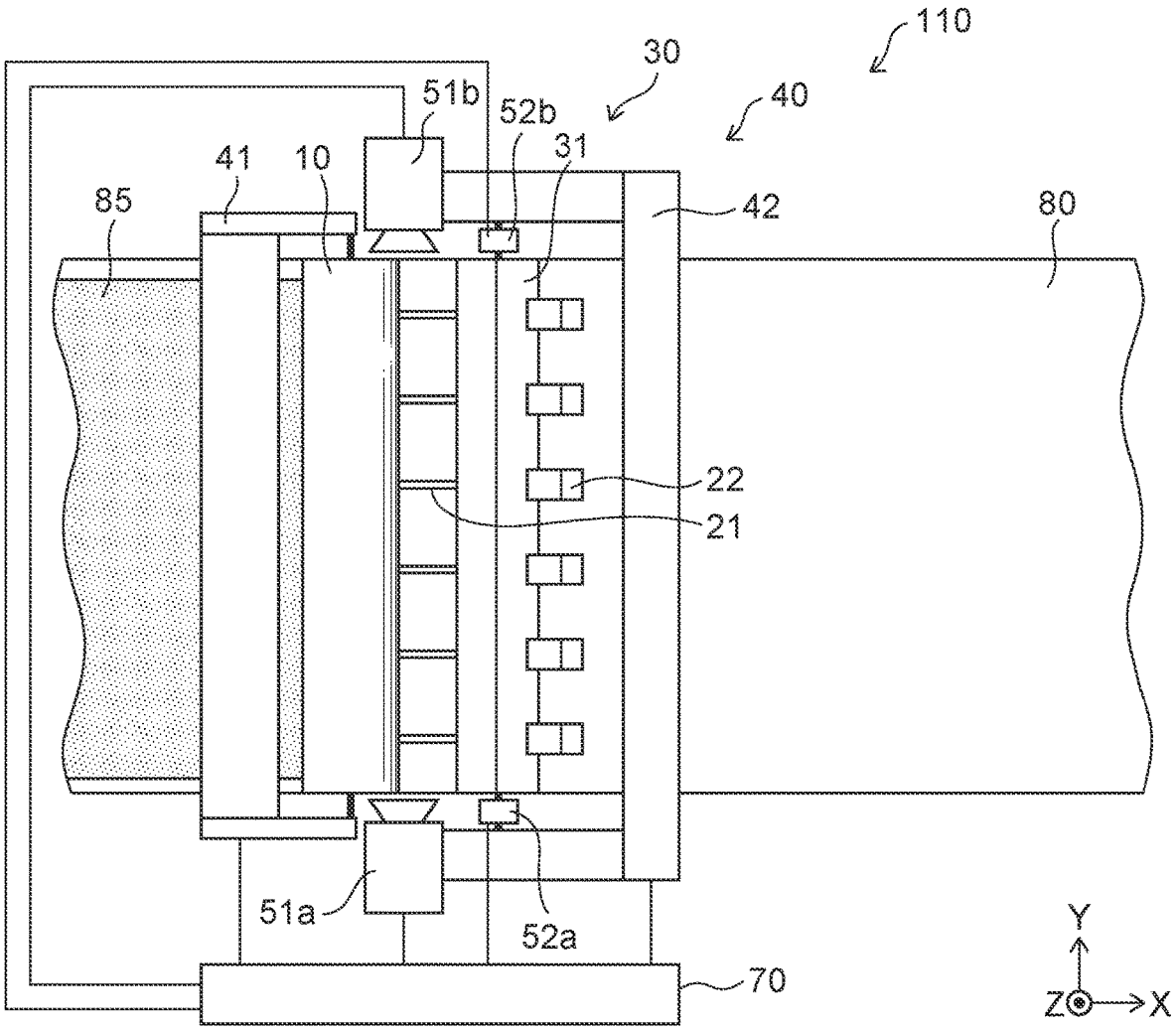

110
30
40
51b
52b
31
41
10
85
42
80
22
21
51a
52a
70
Y
Z
X

FIG. 2A

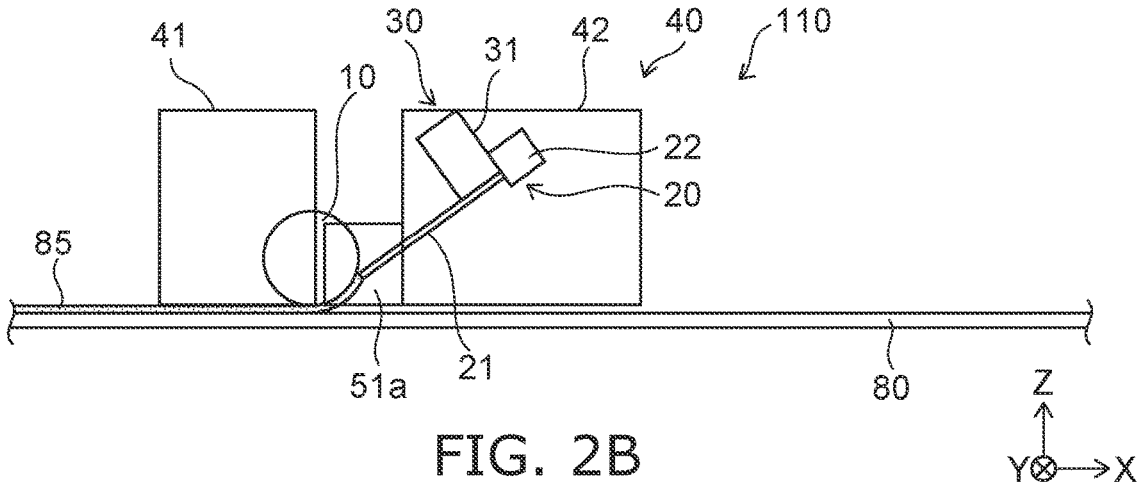

41
30
31
42
40
110
10
22
20
85
51a
21
80
Z
Y
X

FIG. 2B

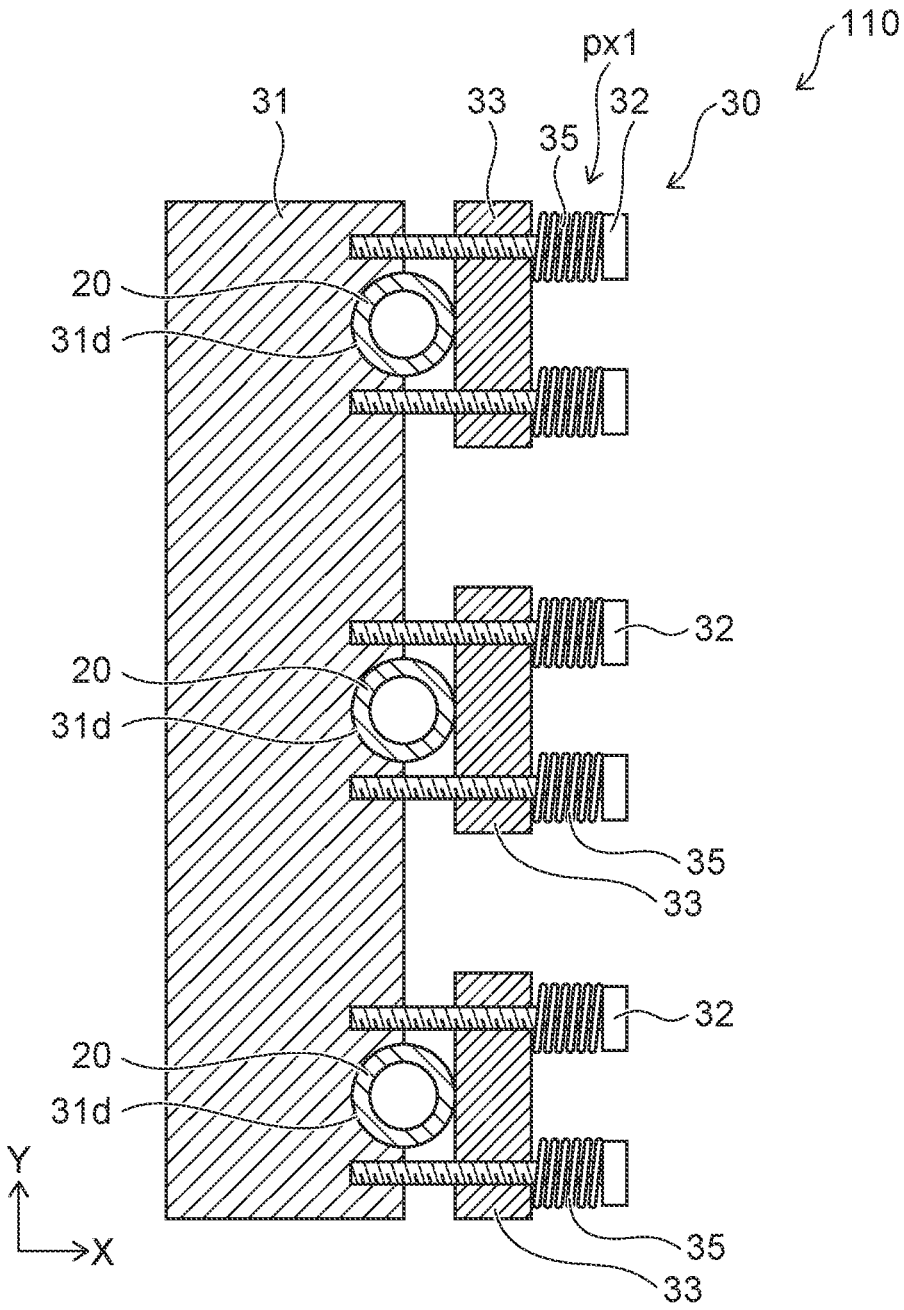


FIG. 3

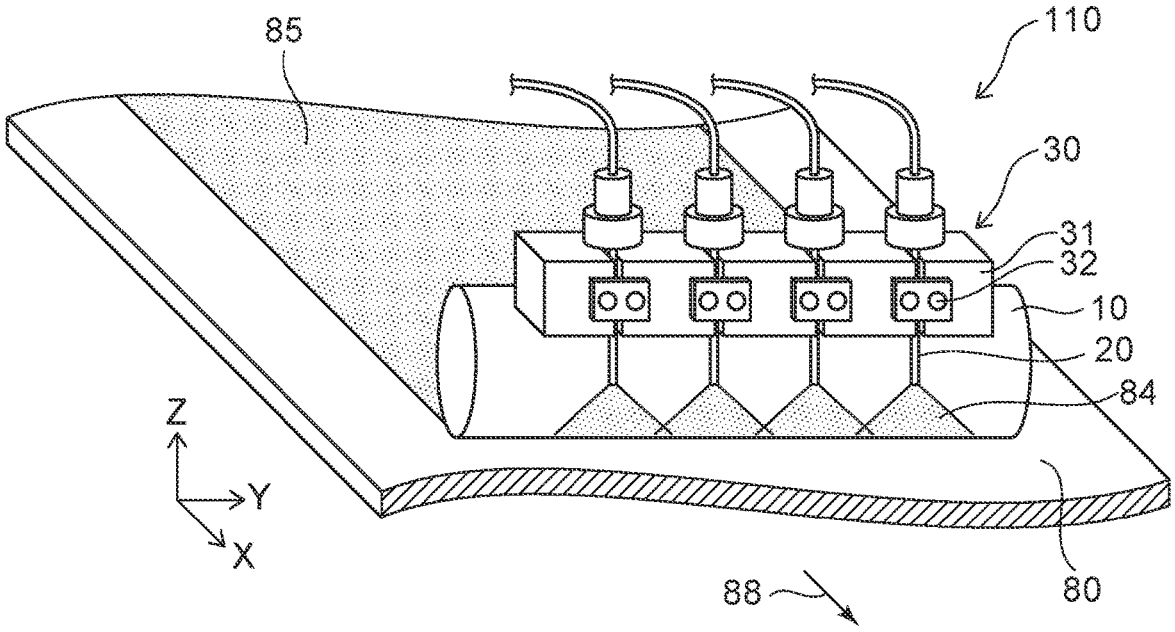


FIG. 4

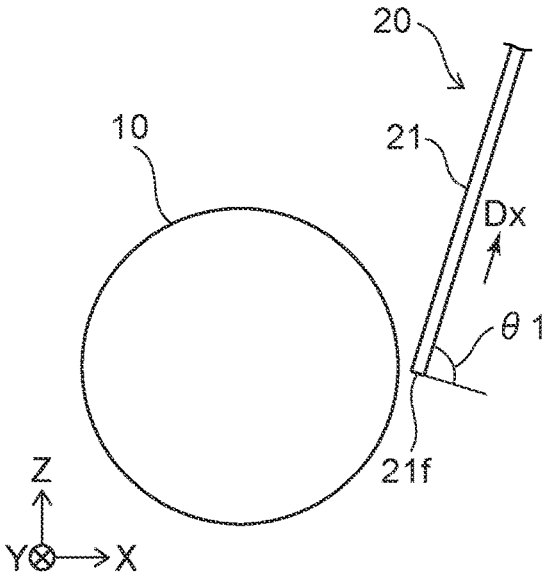


FIG. 5A

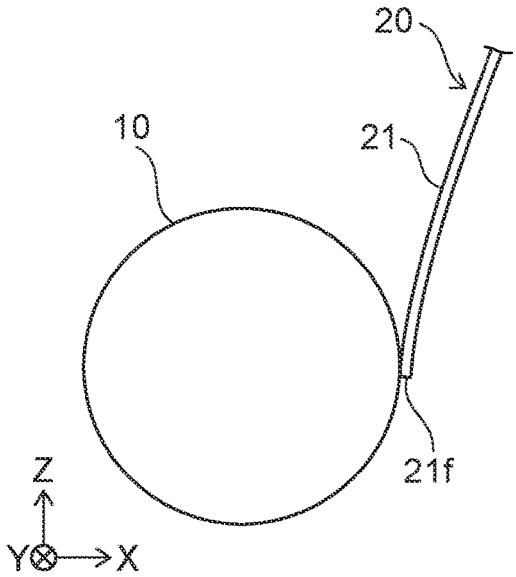


FIG. 5B

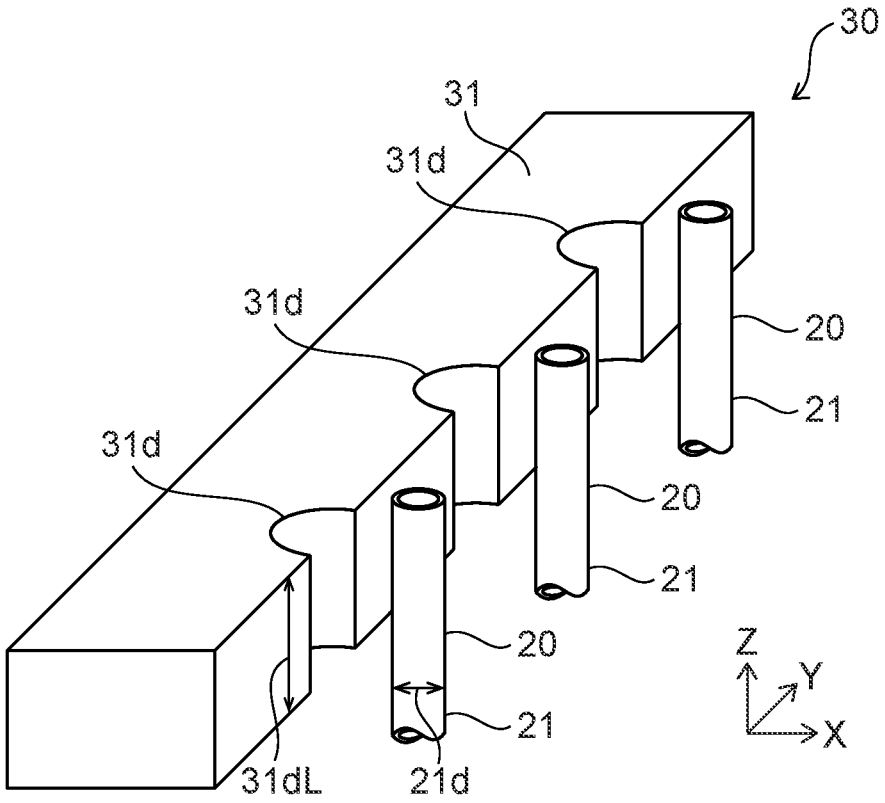


FIG. 6

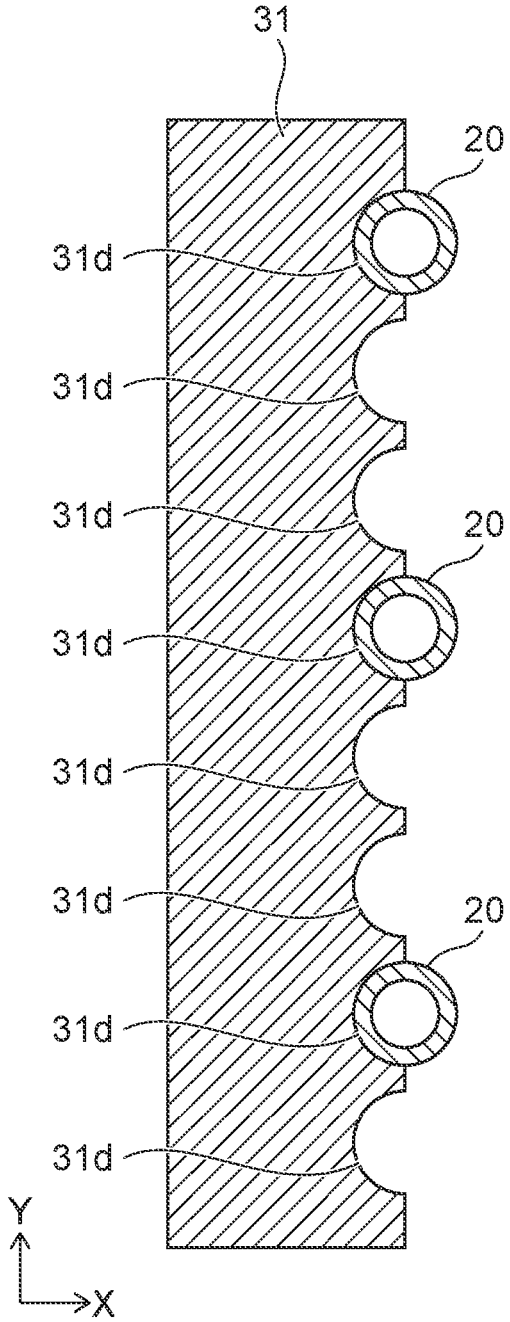


FIG. 7

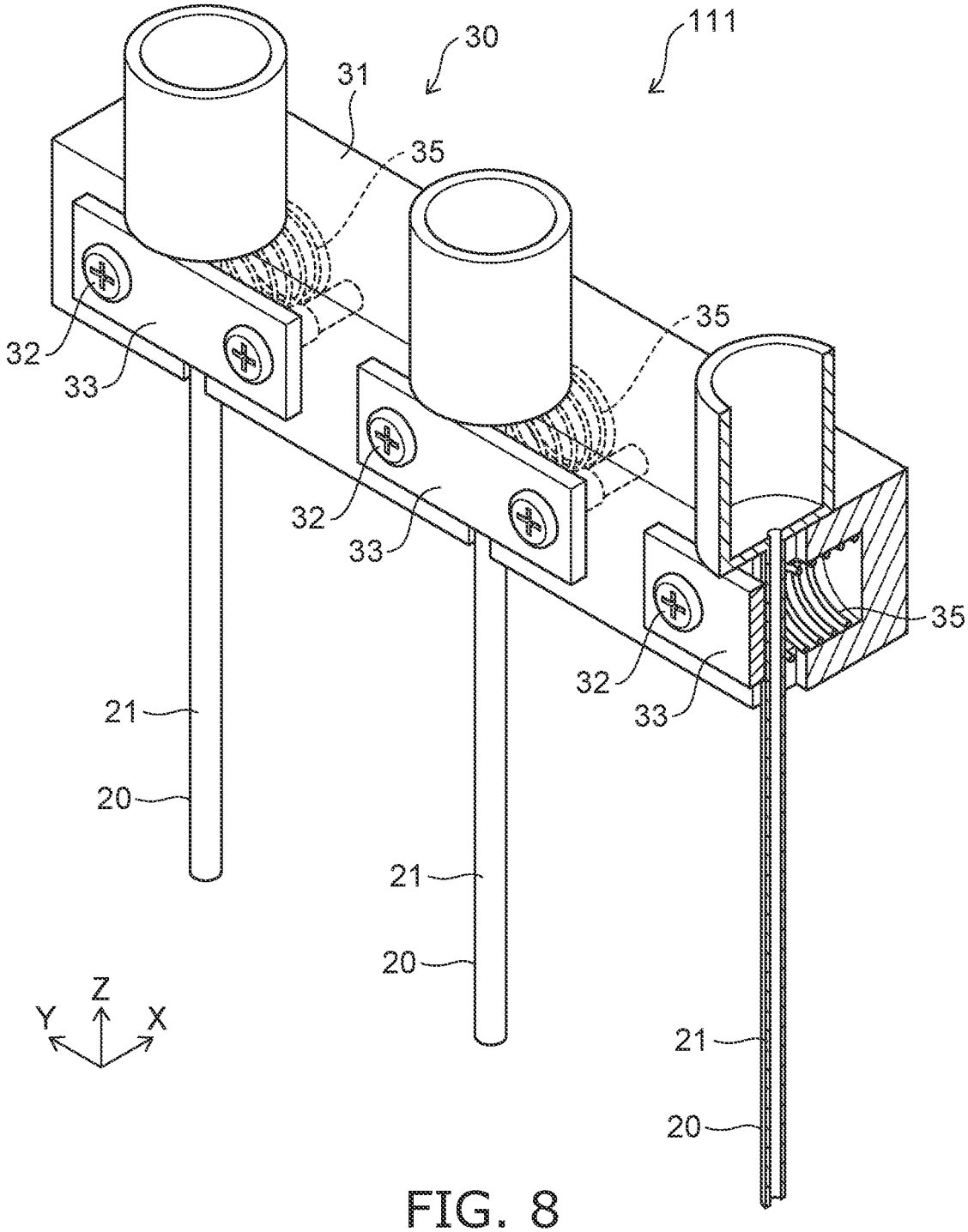


FIG. 8

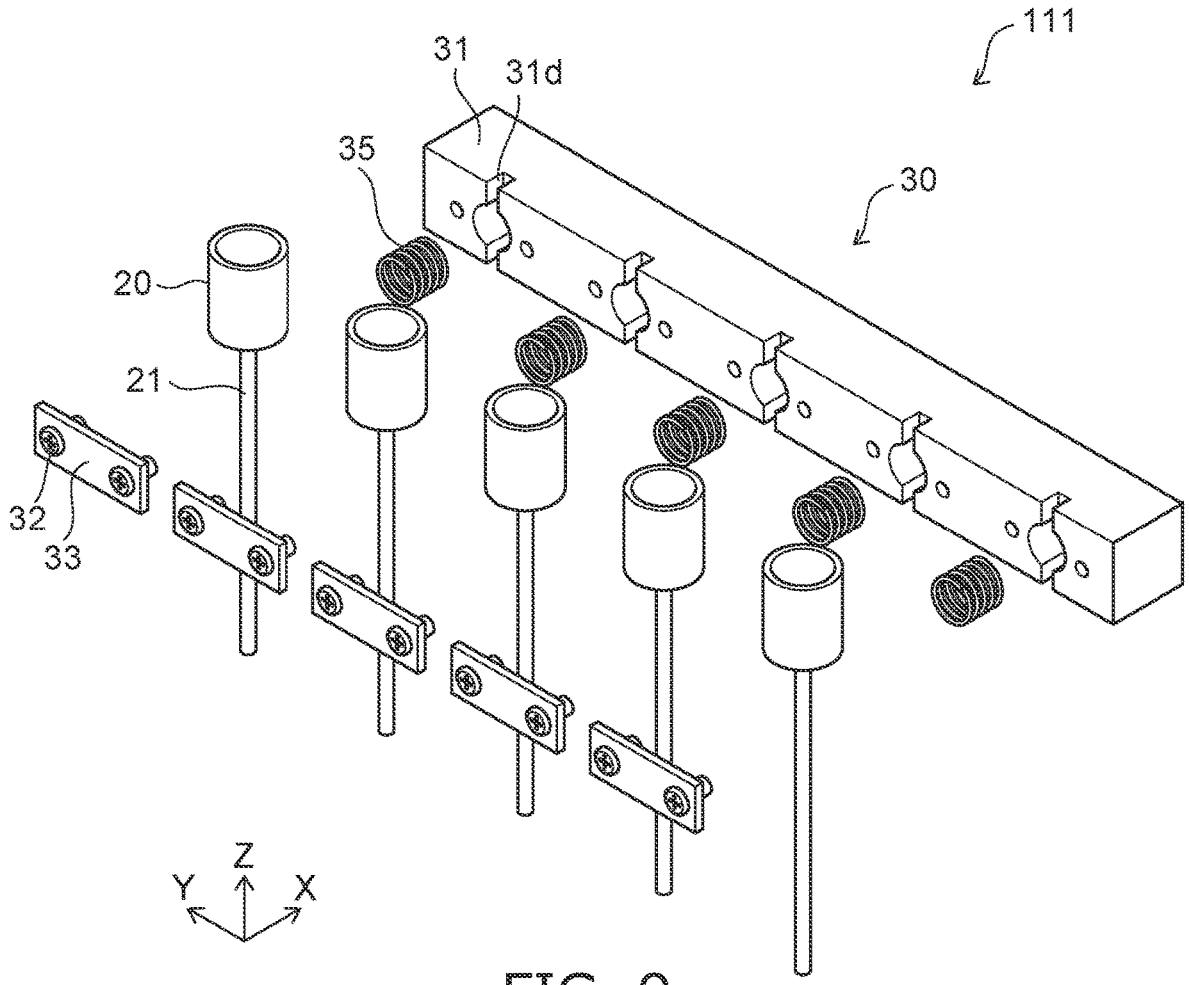


FIG. 9

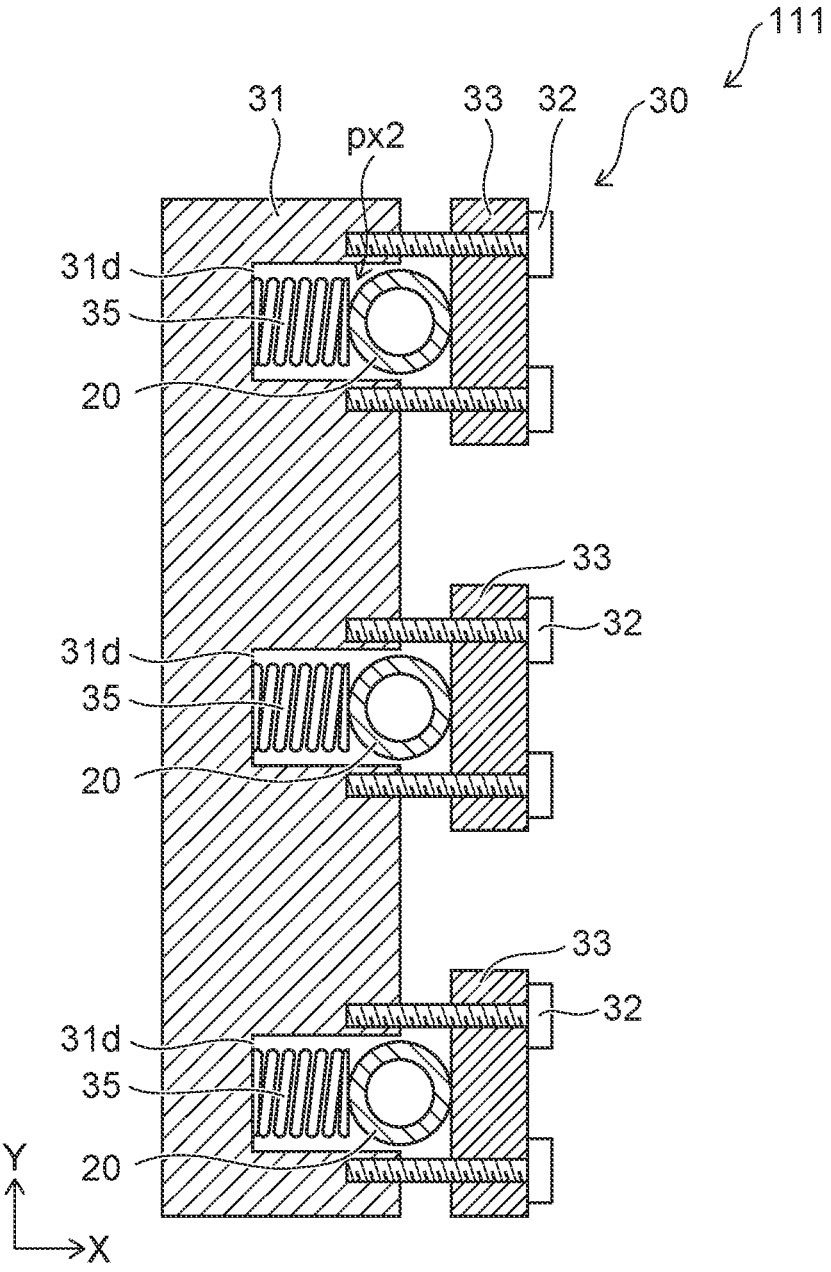


FIG. 10

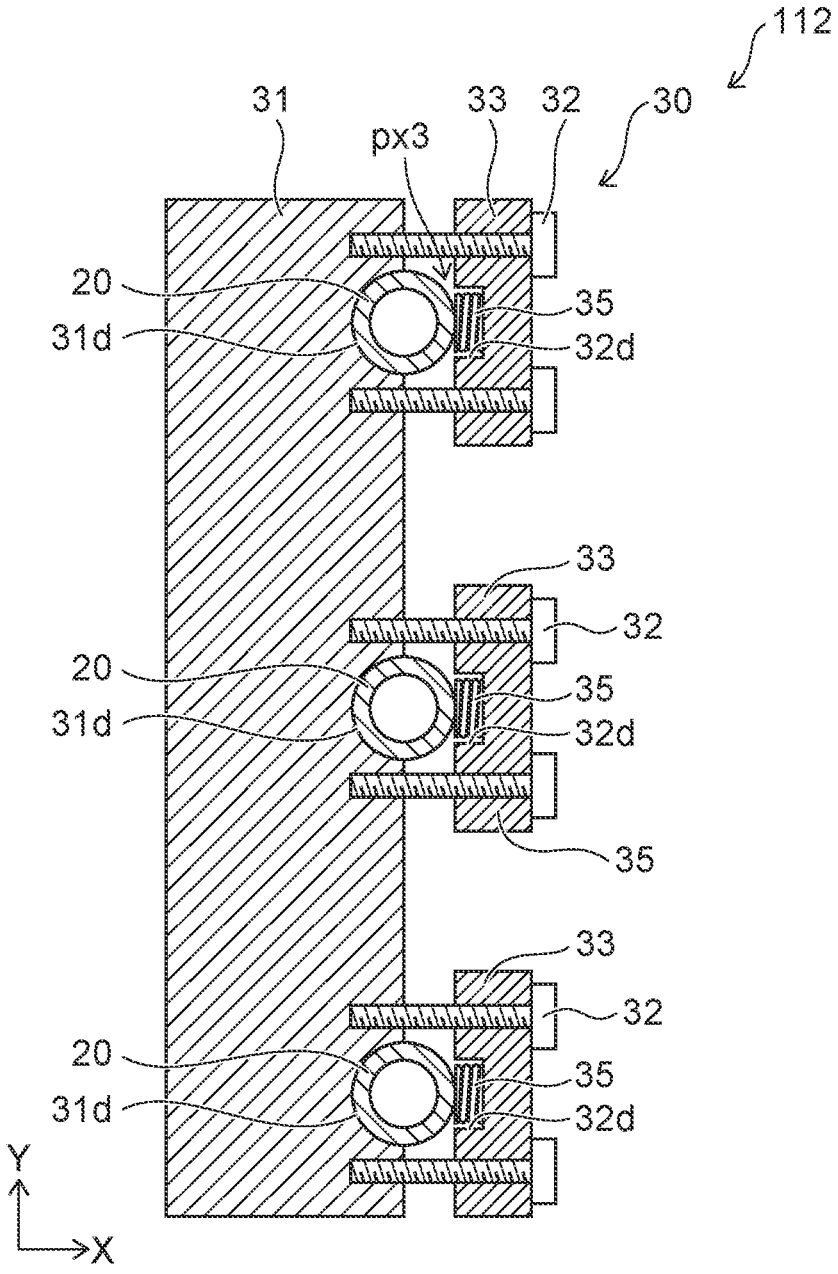
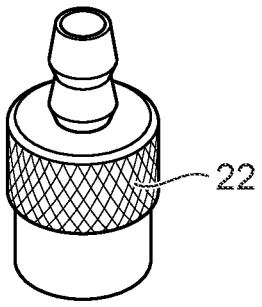

112
31
33
32
30
px3
20
35
31d
32d
33
32
20
35
31d
32d
35
33
32
20
35
31d
32d
Y
X

FIG. 11



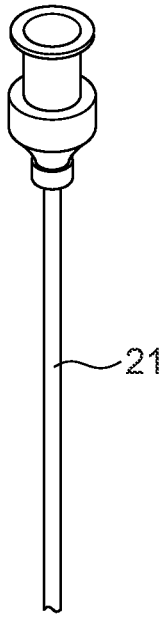


FIG. 12

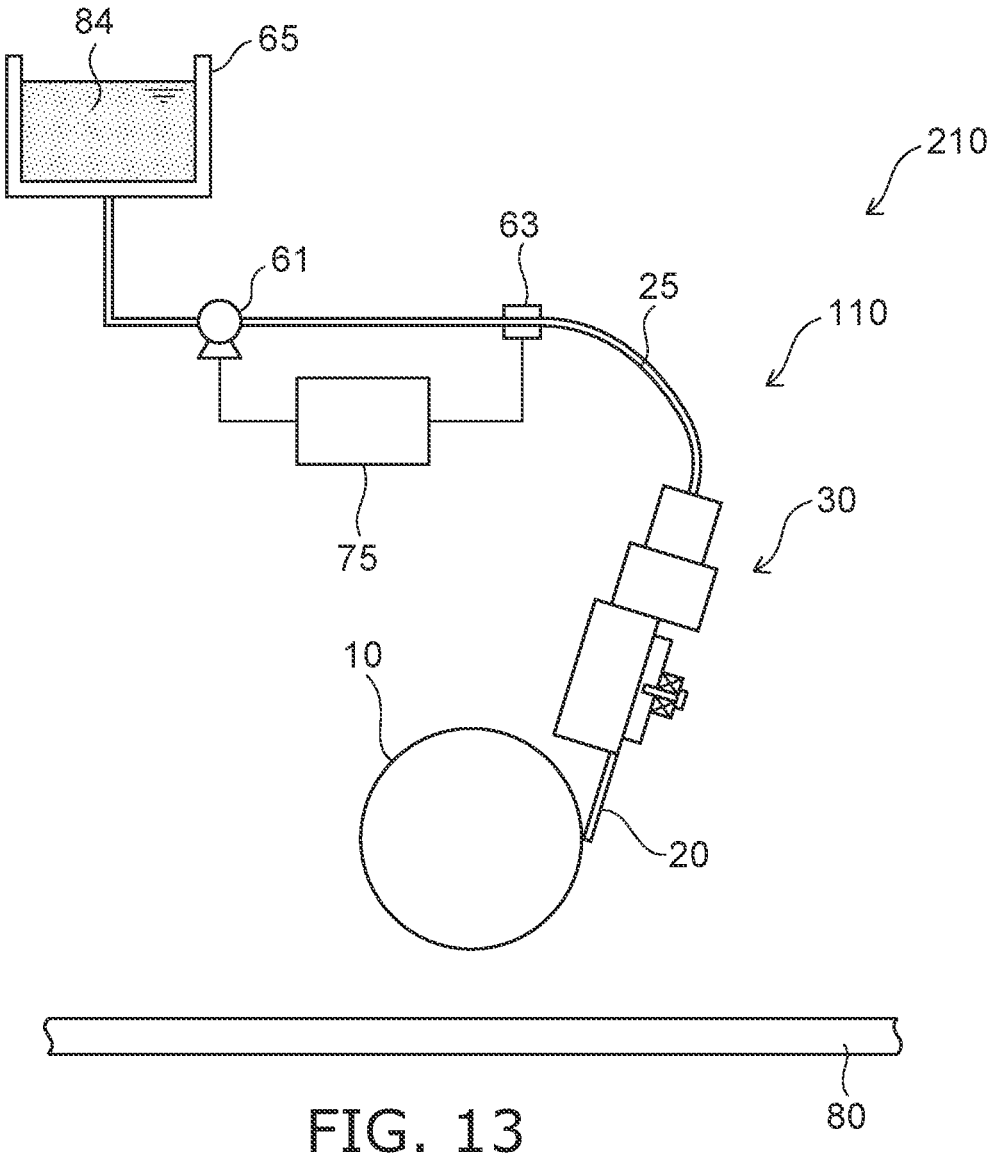


FIG. 13

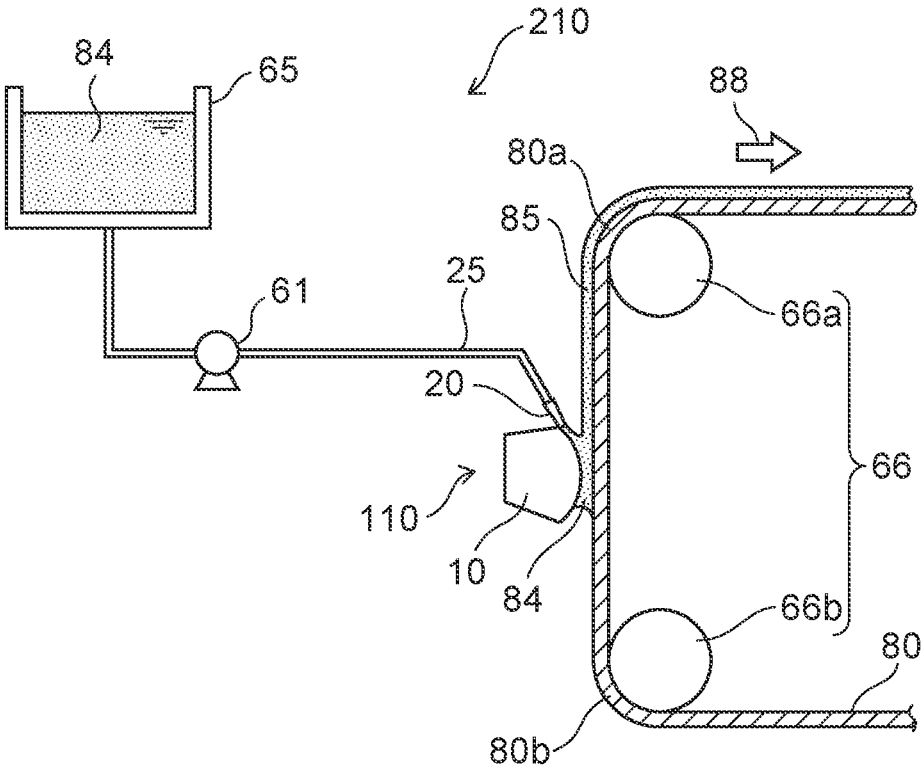


FIG. 14

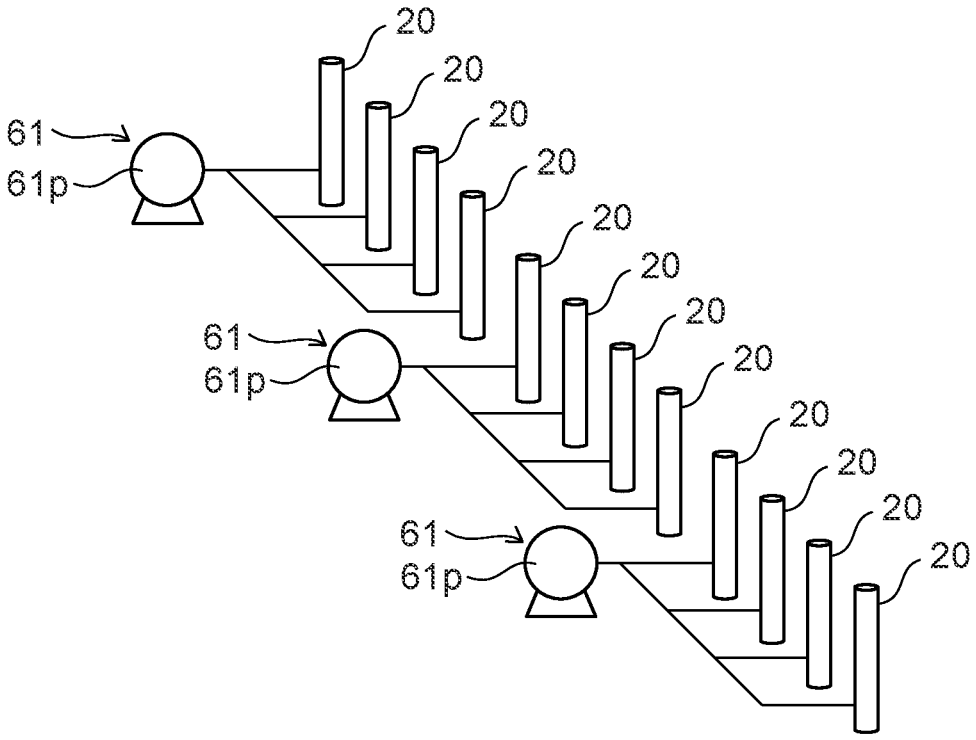


FIG. 15

COATING HEAD, COATING APPARATUS, AND COATING METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation application of International Application PCT/JP2020/009946, filed on Mar. 9, 2020; the entire contents of which are incorporated herein by reference.

FIELD

Embodiments described herein relate generally to a coating head, a coating apparatus, and a coating method.

BACKGROUND

There is a coating head that coats a liquid by using a coating bar. A coating apparatus that can form a uniform coated film is desirable.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A and **1**B are schematic side views illustrating a portion of a coating head according to a first embodiment;

FIGS. **2**A and **2**B are schematic views illustrating the coating head according to the first embodiment;

FIG. **3** is a schematic view illustrating the coating head according to the first embodiment;

FIG. **4** is a schematic perspective view illustrating a portion of the coating head according to the first embodiment;

FIGS. **5**A and **5**B are schematic side views illustrating a portion of the coating head according to the first embodiment;

FIG. **6** is a schematic perspective view illustrating a portion of the coating head according to the first embodiment;

FIG. **7** is a schematic view illustrating the coating head according to the first embodiment;

FIG. **8** is a schematic perspective view illustrating a portion of a coating head according to the first embodiment;

FIG. **9** is a schematic exploded perspective view illustrating a portion of the coating head according to the first embodiment;

FIG. **10** is a schematic view illustrating a portion of the coating head according to the first embodiment;

FIG. **11** is a schematic view illustrating a portion of a coating head according to the first embodiment;

FIG. **12** is a schematic view illustrating a portion of the coating head according to the first embodiment;

FIG. **13** is a schematic view illustrating a coating apparatus according to a second embodiment;

FIG. **14** is a schematic view illustrating the coating apparatus according to the second embodiment; and

FIG. **15** is a schematic view illustrating the coating apparatus according to the second embodiment.

DETAILED DESCRIPTION

According to one embodiment, a coating head includes a coating bar, a plurality of nozzles, a first member, a plurality of second members, a plurality of third members, a plurality of elastic members, and a position controller. The coating bar is configured to face a coating member. The nozzles are configured to supply a liquid toward the coating bar. The first member includes a plurality of first recesses. At least a portion of one of the nozzles is between one of the first recesses and one of the third members. The at least a portion of the one of the nozzles and the one of the third members are fixed to the first member by one of the second members. One of the elastic members is located in at least one of a first position, a second position, or a third position. The first position is between the one of the third members and the one of the second members. The second position is between the at least a portion of the one of the first recesses and the one of the nozzles. The third position is between the at least a portion of the one of the nozzles and the one of the third members. The position controller controls a relative position between the coating bar and the nozzles.

Various embodiments are described below with reference to the accompanying drawings.

The drawings are schematic and conceptual; and the relationships between the thickness and width of portions, the proportions of sizes among portions, etc., are not necessarily the same as the actual values. The dimensions and proportions may be illustrated differently among drawings, even for identical portions.

In the specification and drawings, components similar to those described previously or illustrated in an antecedent drawing are marked with like reference numerals, and a detailed description is omitted as appropriate.

First Embodiment

FIGS. **1**A and **1**B are schematic side views illustrating a portion of a coating head according to a first embodiment.

FIGS. **2**A and **2**B are schematic views illustrating the coating head according to the first embodiment. FIG. **2**A is a top view. FIG. **2**B is a side view. In FIG. **2**B, some of the components are not illustrated for easier viewing of the drawing.

FIG. **3** is a schematic view illustrating the coating head according to the first embodiment. FIG. **3** is a top view of a portion of the coating head.

FIG. **4** is a schematic perspective view illustrating a portion of the coating head according to the first embodiment.

As shown in FIGS. **1**A, **2**A, and **3**, the coating head **110** according to the embodiment includes a coating bar **10**, multiple nozzles **20** (referring to FIG. **3**), a first member **31**, multiple second members **32** (referring to FIG. **3**), multiple third members **33** (referring to FIG. **3**), multiple elastic members **35** (referring to FIG. **3**), and a position controller **40** (referring to FIG. **2**A). The multiple nozzles **20**, the first member **31**, the multiple second members **32**, and the multiple third members **33** are included in a head part **30** (referring to FIG. **1**A).

As shown in FIG. **1**A, the coating bar **10** is configured to face a coating member **80**.

As shown in FIG. **1**B, the multiple nozzles **20** are configured to supply a liquid **84** toward the coating bar **10**. The multiple nozzles **20** are, for example, needle nozzles. FIG. **1**A corresponds to a state in which the liquid **84** is not supplied. FIG. **1**B corresponds to a state in which the liquid **84** is being supplied. As shown in FIG. **1**A, a gap is provided between the coating bar **10** and the coating member **80**. As shown in FIG. **1**B, a meniscus is formed between the coating bar **10** and the coating member **80** when the liquid **84** is supplied to the coating bar **10**. Thus, the coating bar **10** is configured to form a meniscus of the liquid **84** between the coating bar **10** and the coating member **80**. A coated film **85**

is formed of the liquid **84** coated onto the coating member **80**. The target film is obtained by solidifying the coated film **85**.

As shown in FIG. **1**A, the direction from the coating member **80** toward the coating bar **10** is taken as a Z-axis direction. One direction perpendicular to the Z-axis direction is taken as an X-axis direction. A direction perpendicular to the Z-axis direction and the X-axis direction is taken as a Y-axis direction.

As shown in FIG. **1**A, the coating member **80** moves relative to the coating bar **10** along a movement direction **88**. For example, the movement direction **88** is along the X-axis direction.

As shown in FIG. **4**, the coating bar **10** extends in the Y-axis direction. In one example, the coating bar **10** is cylindrical.

In one example as shown in FIG. **1**A, the multiple nozzles **20** extend in a direction that is oblique to the Z-axis direction and is toward the coating bar **10**.

In the example as shown in FIG. **1**A, one of the multiple nozzles **20** includes a nozzle portion **21** and a base part **22**. In the example, the nozzle portion **21** is between one of multiple first recesses **31***d* and one of the multiple third members **33**. The base part **22** is not between the one of the multiple first recesses **31***d* and the one of the multiple third members **33**. For example, the base part **22** is located above the first member **31**. As described below, for example, the nozzle portion **21** may be detachable from the base part **22**. For example, a supply pipe **25** is connected to the base part **22**. As shown in FIG. **1**B, the liquid **84** is supplied to the base part **22** via the supply pipe **25**. The liquid **84** is dispensed from the nozzle portion **21**.

FIG. **3** illustrates the head part **30**. As shown in FIG. **3**, the first member **31** includes the multiple first recesses **31***d*. As shown in FIG. **3**, at least a portion of one of the multiple nozzles **20** is between one of the multiple first recesses **31***d* and one of the multiple third members **33**. For example, at least a portion of the one of the multiple nozzles **20** recited above is the nozzle portion **21**. The at least a portion of the one of the multiple nozzles **20** (e.g., the nozzle portion **21**) and the one of the multiple third members **33** are fixed to the first member **31** by one of the multiple second members **32**.

The first member **31** is a base to which the multiple nozzles **20** are mounted. The multiple second members **32** are, for example, fixing members such as screws, etc. Holes, etc., that engage with the fixing members such as the screws, etc., are provided in the first member **31**. For example, holes through which the fixing members such as the screws, etc., pass are provided in the multiple third members **33**. The fixing members such as the screws, etc., pass through the holes of the multiple third members (the fixing members) and are fixed to the first member **31**. One of the multiple nozzles **20** is located between the first member **31** and one of the multiple third members **33**. The one of the multiple nozzles **20** is fixed to the first member **31** by being clamped between the first member **31** and the one of the multiple third members **33**. The multiple third members **33** are pressing members.

In the example shown in FIG. **3**, one of the multiple elastic members **35** is located at a first position px**1**. The first position px**1** is between the one of the multiple third members **33** and the one of the multiple second members **32**.

As shown in FIG. **2**A, the position controller **40** controls the relative position between the coating bar **10** and the multiple nozzles **20**. In the example, the position controller **40** includes a first holder **41** and a second holder **42**; the first holder **41** holds the coating bar **10**. The second holder **42** holds the multiple nozzles **20**. For example, the second holder **42** holds the multiple nozzles **20** by holding the first member **31**.

The relative position between the coating bar **10** and the multiple nozzles **20** can be controlled by controlling the relative position of the first holder **41** and the second holder **42**.

According to the embodiment, the liquid **84** is supplied from the multiple nozzles **20** toward the coating bar **10**. Thereby, the meniscus can be uniformly spread in a wide area. The multiple nozzles **20** are stably fixed at positions guided by the multiple first recesses **31***d*. The positions of the tips of the multiple nozzles **20** are easily aligned thereby. Because the multiple nozzles **20** are fixed to the positions guided by the multiple first recesses **31***d*, the pitch of the multiple nozzles **20** can be set to the desired state. By the fixation using the elastic member **35**, fluctuation of the coating state due to vibration of the coating bar **10**, etc., can be suppressed. For example, even when a supply pump of the liquid **84** has a pulsatory motion, the elastic member **35** easily reduces the effects of the pulsatory motion.

By providing the multiple elastic members **35** according to the embodiment, a moderate force is applied to the multiple third members **33**. The multiple nozzles **20** are held by a moderate force due to the first member **31** and the multiple third members **33**. For example, the multiple nozzles **20** can be fixed with a moderate tolerance. The amount of the liquid **84** that is dispensed from the multiple nozzles **20** and adhered to the coating bar **10** can be appropriately maintained thereby. Thereby, a uniform coated film **85** can be formed on the coating member **80**. According to the embodiment, a coating head can be provided in which a uniform coated film **85** can be formed. For example, the uniformity of the thickness of the coated film **85** is high.

The position controller **40** includes, for example, an actuator. At least one of the first holder **41** or the second holder **42** may include an actuator. For example, the relative positional relationship between the coating bar **10** and the multiple nozzles **20** can be favorably set. The first holder **41** may include, for example, a 1-axis actuator (e.g., a Z-actuator). The second holder **42** may include, for example, a multi-axis actuator (e.g., an XZθ-actuator).

As shown in FIG. **2**A, the coating head **110** may include first sensors **51***a* and **51***b*. For example, the first sensors **51***a* and **51***b* detect the distance between the coating bar **10** and the coating member **80**.

As shown in FIG. **2**A, the coating head **110** may include a controller **70**. For example, the controller **70** acquires the detection result of the first sensors **51***a* and **51***b* and controls the position controller **40** (e.g., the first holder **41**) based on the detection result. The distance between the coating bar **10** and the coating member **80** is appropriately controlled by the controller **70**. The first sensors **51***a* and **51***b* include, for example, optical elements. The first sensors **51***a* and **51***b* may include, for example, cameras.

As shown in FIG. **2**A, the coating head **110** may include second sensors **52***a* and **52***b*. The second sensors **52***a* and **52***b* detect the stress between the coating bar **10** and the multiple nozzles **20**. For example, the controller **70** acquires the detection result of the second sensors **52***a* and **52***b* and controls the position controller **40** (e.g., the second holder **42**) based on the detection result. The relative position of the coating bar **10** and the multiple nozzles **20** is appropriately controlled by the controller **70**.

As described below, other than the first position px**1**, the multiple elastic members **35** may be located at a second position or a third position. Examples of these positions are described below.

The elastic member **35** includes, for example, a spring. The spring includes at least one of a coil spring, a leaf spring, or a disk spring. The elastic member **35** may include a resin such as rubber, etc. When the elastic member **35** includes a spring, the force is easily controlled favorably. When the elastic member **35** includes a coil spring, the force is easily controlled more favorably. When the third member **33** has a lower elastic modulus than the material of the nozzle **20**, the elastic member **35** can be omitted, or the elastic modulus of the elastic member **35** can be made smaller.

As shown in FIG. **1**A, for example, the multiple nozzles **20** contact the coating bar **10**. The positions of the multiple nozzles **20** with respect to the coating bar **10** are stabilized thereby. A stable supply of the liquid **84** is possible. Because the multiple nozzles **20** contact the coating bar **10**, the uniformity of the coated film **85** is high compared to when the multiple nozzles **20** do not contact the coating bar **10**.

For example, the state in which the multiple nozzles **20** contact the coating bar **10** and the state in which the multiple nozzles **20** are separated from the coating bar **10** may be formable by the position controller **40** (e.g., at least one of the first holder **41** or the second holder **42**). The multiple nozzles **20** and the coating bar **10** can move relatively in the X-axis direction.

At least one of the first holder **41** or the second holder **42** may be configured to apply, to at least one of the coating bar **10** or the multiple nozzles **20**, stress that has at least one of the orientation from the coating bar **10** toward the multiple nozzles **20** or the orientation from the multiple nozzles **20** toward the coating bar **10**.

FIGS. **5**A and **5**B are schematic side views illustrating a portion of the coating head according to the first embodiment.

FIG. **5**A shows a state in which the multiple nozzles **20** are separated from the coating bar **10**. FIG. **5**B shows a state in which the multiple nozzles **20** contact the coating bar **10**. For example, stress that is generated by at least one of the first holder **41** or the second holder **42** is applied to at least one of the coating bar **10** or the multiple nozzles **20**. As shown in FIG. **5**B, at least one of the multiple nozzles **20** may reversibly bend according to the stress. The multiple nozzles **20** may have moderate flexibility. The multiple nozzles **20** may be able to deflect.

As shown in FIG. **5**A, each (one) of the multiple nozzles **20** includes an end surface **21***f* in the state in which the multiple nozzles **20** are separated from the coating bar **10**. The liquid **84** is dispensed from the end surface **21***f*. It is favorable for an angle θ**1** between the end surface **21***f* and an extension direction Dx in which each (one) of the multiple nozzles **20** extends to be, for example, about 90 degrees. According to the embodiment, the angle θ**1** is, for example, not less than 80 degrees and not more than 100 degrees. By such an angle, for example, the contact state between the coating bar **10** and the tip of the nozzle **20** does not easily change even when the fixed state of the nozzle **20** (e.g., a rotational position having the extension direction Dx as the axis) changes. A stable coating is more possible. By such an angle, damage of the coating bar **10** can be suppressed.

In one example, the length of the nozzle **20** is, for example, not less than 2 cm and not more than 10 cm. The length of the nozzle **20** may be, for example, not less than 3 cm and not more than 6 cm. In one example, the inner diameter of the nozzle **20** is not less than 0.15 mm and not more than 2 mm. By setting the inner diameter to be not less than 0.15 mm, the pump pressure that is necessary for supplying the liquid **84** to the nozzle **20** is relaxed. By setting the inner diameter to be not more than 2 mm, the pulsatory motion of the liquid **84** is easily suppressed. A more uniform coated film is easily obtained thereby.

FIG. **6** is a schematic perspective view illustrating a portion of the coating head according to the first embodiment.

FIG. **6** illustrates the first member **31** and the multiple nozzles **20**. In FIG. **6**, the first member **31** and the multiple nozzles **20** are drawn as being separated from each other for easier viewing of the drawing.

As shown in FIG. **6**, the multiple first recesses **31***d* are provided in the first member **31**. Each (one) of the multiple first recesses **31***d* extends along the direction in which at least a portion of each (one) of the multiple nozzles **20** (e.g., the nozzle portion **21**) extends. At least a portion of the nozzle portion **21** engages such a first recess **31***d*. The position of the nozzle portion **21** is stabilized.

As shown in FIG. **6**, at least a portion of each (one) of the multiple first recesses **31***d* may be curved. For example, the cross-sectional shape of the first recess **31***d* is "U-shaped". According to the embodiment, the cross-sectional shape of the first recess **31***d* may be "V-shaped". The cross-sectional shape may be rectangular. When the cross-sectional shape of the first recess **31***d* is "U-shaped", the force that is applied to the nozzle portion **21** is easily made uniform. For example, damage of the nozzle portion **21** can be suppressed.

According to the embodiment, when the cross-sectional shape of the first recess **31***d* is curved, the curvature radius of the cross-sectional shape of the first recess **31***d* is, for example, not less than the curvature radius of the cross-sectional shape of the outer surface of the nozzle portion **21**.

At least a portion of the nozzle portion **21** enters the first recess **31***d*. In one example, another portion of the nozzle portion **21** is outside the first recess **31***d*. In one example, the length of the portion of the nozzle portion **21** that is outside the first recess **31***d* is not less than ⅓ and not more than ⅔ of the outer diameter of the nozzle portion **21**. An outer diameter **21***d* of the nozzle portion **21** is, for example, not less than 0.4 mm and not more than 3 mm. A length **31**dL of the first recess **31***d* (referring to FIG. **6**) is, for example, not less than 1 cm and not more than 3 cm.

FIG. **7** is a schematic view illustrating the coating head according to the first embodiment.

FIG. **7** is a top view of a portion of the coating head. The second member **32**, the third member **33**, and the elastic member **35** are not illustrated in FIG. **7**.

As shown in FIG. **7**, the multiple nozzles **20** may be provided in a portion of the multiple first recesses **31***d*. In the example of FIG. **7**, for example, the pitch of the multiple nozzles **20** is greater than the pitch of the multiple first recesses **31***d*. The nozzle **20** is not provided at some of the multiple first recesses **31***d*. For example, the pitch of the multiple nozzles **20** may be able to be modified according to the characteristics of the liquid **84**. For example, the pitch of the multiple nozzles **20** can be easily modified by providing the multiple first recesses **31***d* at a small pitch and by providing the multiple nozzles **20** at a portion of the multiple first recesses **31***d*.

According to the embodiment, the cross-sectional shape of the coating bar **10** is arbitrary. The cross-sectional shape of the coating bar is, for example, circular, flattened circular, or polygonal. A portion of the cross-sectional shape may be

curvilinear; and another portion may be linear. For example, the cross-sectional shape of the surface of the coating bar **10** facing the coating member **80** may be curvilinear.

As shown in FIG. **1**A, a surface **10***s* (e.g., the side surface) of the coating bar **10** contacts the multiple nozzles **20**. As shown in FIG. **1**A, the surface **10***s* may be a curved surface. According to the embodiment, the surface **10***s* may be a plane. When the surface **10***s* is a plane, for example, the contact state between the coating bar **10** and the multiple nozzles **20** is easily made uniform.

The coating bar **10** includes, for example, at least one selected from the group consisting of stainless steel, aluminum, titanium, and glass. It is more favorable for the coating bar **10** to include stainless steel or aluminum. Thereby, the processing of the coating bar **10** is easier. In one example, the surface of the coating bar **10** is a mirror surface. The surface of the coating bar **10** may include a fine unevenness. When a fine unevenness is provided, for example, a high wettability with the liquid **84** is obtained. A maximum height Rz of the unevenness is, for example, not less than 5 μm and not more than 50 μm. An arithmetic average surface roughness Ra of the unevenness is, for example, not less than 1 μm and not more than 10 μm. For example, the unevenness is made by sandblasting.

FIG. **8** is a schematic perspective view illustrating a portion of a coating head according to the first embodiment.

FIG. **9** is a schematic exploded perspective view illustrating a portion of the coating head according to the first embodiment.

FIG. **10** is a schematic view illustrating a portion of the coating head according to the first embodiment.

FIG. **10** is a top view of a portion of the coating head.

FIGS. **8** to **10** illustrate the head part **30** of the coating head **111** according to the embodiment. Other than the head part **30**, the configuration of the coating head **111** may be similar to that of the coating head **110**. An example of the head part **30** of the coating head **111** will now be described.

As shown in FIGS. **8** to **10**, the head part **30** includes the multiple nozzles **20**, the first member **31**, the multiple second members **32**, the multiple third members **33**, and the multiple elastic members **35**. The first member **31** includes the multiple first recesses **31***d*. At least a portion of one of the multiple nozzles **20** is between one of the multiple first recesses **31***d* and one of the multiple third members **33**. The at least a portion of the one of the multiple nozzles **20** recited above and the one of the multiple third members **33** recited above are fixed to the first member **31** by one of the multiple second members **32**.

One of the multiple elastic members **35** is located at a second position px**2** (referring to FIG. **10**). The second position px**2** is between the at least a portion of the one of the multiple first recesses **31***d* recited above and the one of the multiple nozzles **20** recited above.

In the coating head **111** that includes such a head part **30** as well, a coating head can be provided in which a uniform coated film **85** can be formed.

FIG. **11** is a schematic view illustrating a portion of a coating head according to the first embodiment.

FIG. **11** is a top view of a portion of the coating head.

FIG. **11** illustrates the head part **30** of the coating head **112** according to the embodiment. Other than the head part **30**, the configuration of the coating head **112** may be similar to the coating head **110**. An example of the head part **30** of the coating head **112** will now be described.

In the coating head **112** as well, the head part **30** includes the multiple nozzles **20**, the first member **31**, the multiple second members **32**, the multiple third members **33**, and the multiple elastic members **35**. The first member **31** includes the multiple first recesses **31***d*. In the coating head **112**, one of the multiple elastic members **35** is located at a third position px**3**. The third position px**3** is between at least a portion of one of the multiple nozzles **20** and one of the multiple third members **33**.

In the coating head **112** that includes such a head part **30** as well, a coating head can be provided in which a uniform coated film **85** can be formed.

In the example, one of the multiple third members **33** includes a second recess **32***d*. At least a portion of one of the multiple nozzles **20** is between the second recess **32***d* and one of the multiple first recesses **31***d*. By providing the second recess **32***d*, the precision of the positions of the multiple nozzles **20** can be further increased.

According to the embodiment, the elastic member **35** may be located in at least one of the first position px**1** recited above, the second position px**2** recited above, or the third position px**3** recited above.

FIG. **12** is a schematic view illustrating a portion of the coating head according to the first embodiment.

As shown in FIG. **12**, one of the multiple nozzles **20** includes the nozzle portion **21** and the base part **22**. In the example, the nozzle portion **21** and the base part **22** are detachable. Thereby, for example, cleaning of the nozzle portion **21** and the base part **22** is easier. For example, replacement of at least one of the nozzle portion **21** or the base part **22** is easier. For example, the bottom portion of the base part **22** is located at the upper portion of the first member **31**. The tips of the multiple nozzles **20** are easily aligned thereby.

Second Embodiment

A second embodiment relates to a coating apparatus.

FIG. **13** is a schematic view illustrating the coating apparatus according to the second embodiment.

As shown in FIG. **13**, the coating apparatus **210** according to the embodiment includes the coating head according to the first embodiment (in the example, the coating head **110**) and a supplier **61**. The supplier **61** supplies the liquid **84** to the multiple nozzles **20**. The supplier **61** includes, for example, a pump. In the example, a tank **65** in which the liquid **84** is stored is provided. The supplier **61** is connected with the tank **65**. The supplier **61** is connected with the nozzle **20** by the supply pipe **25**. The liquid **84** is supplied from the supplier **61** to the nozzle **20**; and the liquid **84** is supplied from the nozzle **20** toward the coating bar **10**. The coating head that is included in the coating apparatus **210** may be any coating head according to the first embodiment.

A liquid sensor **63** may be provided as shown in FIG. **13**. The liquid sensor **63** detects the supply rate of the liquid **84** toward the multiple nozzles **20**. For example, the liquid sensor **63** measures the flow rate of the liquid **84** by utilizing the Doppler effect.

A supply controller **75** may be provided. The supply controller **75** controls the supplier **61** based on the supply rate detected by the liquid sensor **63**. A more uniform coated film is easily obtained thereby.

FIG. **14** is a schematic view illustrating the coating apparatus according to the second embodiment.

As shown in FIG. **14**, the coating apparatus **210** may include a coating member holder **66**. The coating member holder **66** holds the coating member **80**. The coating member holder **66** moves the coating member **80** relative to the coating head (in the example, the coating head **110**).

In the example, the coating member **80** includes a roll-shaped film. The coating member holder **66** includes a first holding mechanism **66***a* and a second holding mechanism **66***b*. The first holding mechanism **66***a* holds a first portion **80***a* of the roll-shaped film (the coating member **80**). The second holding mechanism **66***b* holds a second portion **80***b* of the roll-shaped film (the coating member **80**). The first holding mechanism **66***a* and the second holding mechanism **66***b* are, for example, rollers.

In the coating apparatus **210**, a meniscus of the liquid **84** is formed between the coating bar **10** and the coating member **80**; and the liquid **84** is coated onto the coating member **80**. The coated film **85** is formed of the liquid **84** on the coating member **80**. The target film is obtained by drying and solidifying the coated film **85**.

For example, the coating apparatus **210** may include a mechanism that can modify the position of the coating head **110**. It is favorable for the coating member **80** to be a roll-shaped film. The coating is possible with high productivity.

As shown in FIG. **14**, the position of at least a portion of the coating member holder **66** is higher than the position of the supplier **61**. In the example, the position of the first holding mechanism **66***a* is higher than the position of the supplier **61**. By such a configuration, for example, the effects of the pulsatory motion of the supplier **61** are easily suppressed.

According to the embodiment, it is favorable for the movement direction **88** of the coating member **80** to be a direction that is upward from below. Thereby, gravity is applied to the meniscus. Even when coating at a high speed, a uniform coated film **85** is easily obtained thereby. The movement direction **88** may be oblique to the vertical direction. The angle between the movement direction **88** and the vertical direction is, for example, not more than 30°.

As shown in FIG. **14**, it is favorable for the multiple nozzles **20** to supply the liquid **84** to the coating bar **10** from above the coating bar **10**. For example, dripping of the liquid **84** can be suppressed.

According to the embodiment, a joint at which the supply pipe **25** and the nozzle **20** can be detached may be provided.

According to the embodiment, for example, multiple supply pipes **25** that supply the liquid **84** to the multiple nozzles **20** from one tank **65** are provided. Thereby, for example, the liquid can be easily supplied to the multiple nozzles **20** with a uniform pressure.

According to the embodiment, a cleaning mechanism that cleans the coating bar **10** may be provided. For example, the cleaning mechanism sprays or emits a solvent (e.g., water). For example, the cleaning mechanism may be configured to apply an ultrasonic wave. According to the embodiment, a recovery mechanism that recovers the excess liquid may be provided.

FIG. **15** is a schematic view illustrating the coating apparatus according to the second embodiment.

As shown in FIG. **15**, the supplier **61** may include multiple pumps **61***p*. In the example, the number of the multiple nozzles **20** is an integer multiple of the multiple pumps **61***p*. The number of the pumps **61***p* can be reduced thereby. It is more favorable for the number of the nozzles **20** to which the liquid **84** is supplied from one pump **61***p* to be 2^n (n being an integer).

Third Embodiment

A third embodiment relates to a coating method. The coating method according to the embodiment coats the liquid **84** onto the coating member **80** by using the coating head according to the first embodiment. The coating method according to the embodiment coats the liquid **84** onto the coating member **80** by using the coating apparatus according to the second embodiment. A coating method can be provided in which a uniform coated film can be formed.

According to the embodiment, the pitch of the multiple nozzles **20** may be determined based on the viscosity of the liquid **84** and the surface tension of the liquid **84**. A processor that outputs an appropriate pitch based on the viscosity and the surface tension may be provided.

For example, a film that is included in a solar cell may be formed by the coating head according to the embodiment. For example, the coating member **80** is a roll-shaped film.

An example of experiment results will now be described. In the experiments, the coating member **80** is a roll-shaped PET film. The width (the length in the Y-axis direction) of the PET film is 300 mm. A light-transmissive conductive film is formed on a roll-shaped film by a sputtering apparatus that is adapted to roll-to-roll. The conductive film is a stacked film of ITO/Ag alloy/ITO. The sheet resistance of the conductive film is about 5Ω/□. The conductive film is patterned into the desired configuration by laser irradiation.

In the experiments, the cross-sectional shape of the coating bar **10** is substantially trapezoidal. The bottom portion of the cross-sectional shape of the coating bar **10** is circular arc-like with a curvature of 80 mm. The length in the Y-axis direction of the coating bar **10** is 300 mm. The coating bar **10** is SUS 303.

The length in the Y-axis direction of the first member **31** is 320 mm. The pitch of the multiple first recesses **31***d* is 20 mm. The cross-sectional shape of the first recess **31***d* is "V-shaped". The length in the Y-axis direction of the multiple third members **33** is 30 mm. The length of the nozzle **20** is about 50 mm. The nozzle **20** includes stainless steel. The inner diameter of the nozzle **20** is 0.8 mm. The nozzle **20** is fixed to the first recess **31***d* of the first member **31** by the second member **32** by using the third member **33** and a spring (the elastic member **35**). The supply pipe **25** is connected to the base part **22** of the nozzle **20**. The supply pipe **25** is a fluorocarbon resin tube. The base part **22** and the supply pipe **25** are connected by a detachable connection member.

In a first experiment, a first liquid is a PEDOT/PSS aqueous dispersion liquid. The first liquid is one of the liquid **84**. For example, a hole transport layer of a solar cell can be made from the first liquid. The first liquid is supplied from the multiple nozzles **20** toward the coating bar **10**. The dispense amount of the first liquid from one of the multiple nozzles **20** is, for example, 20 μL/s. The movement speed of the coating member **80** is about 83 mm/s. The coated film **85** of the first liquid is dried in a hot air drying furnace adapted to roll-to-roll.

A second liquid is coated onto the coated film **85** (the hole transport layer) recited above after drying. In the second liquid, 8 mg of PTB7 ([poly{4,8-bis[(2-ethylhexyl)oxy]benzo[1,2-b:4,5-b']dithiophene-2,6-diyl-1t-alt-3-fluoro-2-[(2-ethylhexyl)carbonyl]thieno[3,4-b]thiophene-4,6-diyl}]/p-type semiconductor) and 12 mg of $PC_{70}BM$ ([6,6]phenyl-C_{71}-methyl esther butyrate/n-type semiconductor) are dispersed in 1 mL of monochlorobenzene. The second liquid is one of the liquid **84**. An organic active layer of a solar cell is formed of the second liquid.

In the coating of the second liquid, the distance between the coating bar **10** and the coating member **80** is 300 μm. In the coating of the second liquid **84**, the dispense amount of the second liquid from one of the multiple nozzles **20** is, for

example, 40 μL/s. The movement speed of the coating member **80** is about 83 mm/s. The coated film **85** of the second liquid is dried in a hot air drying furnace adapted to roll-to-roll.

In such a first experiment, the thickness unevenness of the coated film **85** of the first liquid and the coated film **85** of the second liquid is not more than 5%.

In a second experiment, the coating bar **10** includes a micro unevenness. The maximum height Rz of the unevenness is about 20 μm. The arithmetic average surface roughness Ra of the unevenness is about 3 μm. In the supply of the first liquid of the second experiment, the dispense amount of the first liquid from one of the multiple nozzles **20** is, for example, 25 μL/s. In the supply of the first liquid of the second experiment, the dispense amount of the first liquid from one of the multiple nozzles **20** is, for example, 45 μL/s. In such a second experiment, the thickness unevenness of the coated film **85** of the first liquid and the coated film **85** of the second liquid is not more than 7%.

In a third experiment, the elastic member **35** is not included in the coating head. Otherwise, the conditions of the third experiment are similar to those of the first experiment. In the third experiment, the thickness unevenness of the coated film **85** of the first liquid is not less than 10%. In the third experiment, the thickness unevenness of the coated film **85** of the second liquid is not less than 10%.

In a fourth experiment, the first recess **31***d* is not provided in the first member **31** of the coating head. Otherwise, the conditions of the fourth experiment are similar to those of the first experiment. In the fourth experiment, the thickness unevenness of the coated film **85** of the first liquid is not less than 15%. In the fourth experiment, the thickness unevenness of the coated film **85** of the second liquid is not less than 15%. In the fourth experiment, the multiple nozzles **20** cannot uniformly contact the coating bar **10**.

For example, there is an organic thin film solar cell that uses an organic semiconductor or an organic/inorganic hybrid solar cell. For example, an inexpensive solar cell is obtained by forming the layer included in the solar cell by coating. According to the embodiment, for example, a uniform coated film is obtained by roll-to-roll coating. According to the embodiment, for example, a meniscus is formed between the coating bar **10** and the coating member **80**. The positions of the multiple nozzles **20** are determined by being guided by grooves (the first recesses **31***d*). The multiple nozzles **20** are fixed to the first member **31** by using the elastic member **35**.

Embodiments include the following configurations (e.g., technological proposals).

Configuration 1

A coating head, comprising:

a coating bar configured to face a coating member;

a plurality of nozzles configured to supply a liquid toward the coating bar;

a first member including a plurality of first recesses;

a plurality of second members;

a plurality of third members, at least a portion of one of the plurality of nozzles being between one of the plurality of first recesses and one of the plurality of third members, the at least a portion of the one of the plurality of nozzles and the one of the plurality of third members being fixed to the first member by one of the plurality of second members;

a plurality of elastic members, one of the plurality of elastic members being located in at least one of a first position, a second position, or a third position, the first position being between the one of the plurality of third members and the one of the plurality of second members, the second position being between the at least a portion of the one of the plurality of first recesses and the one of the plurality of nozzles, the third position being between the at least a portion of the one of the plurality of nozzles and the one of the plurality of third members; and

a position controller controlling a relative position between the coating bar and the plurality of nozzles.

Configuration 2

The coating head according to Configuration 1, wherein

the plurality of nozzles contacts the coating bar.

Configuration 3

The coating head according to Configuration 1 or 2, wherein

the one of the plurality of first recesses extends along a direction in which the at least a portion of the one of the plurality of nozzles extends.

Configuration 4

The coating head according to any one of Configurations 1 to 3, wherein

a surface of the coating bar includes an unevenness, and

a maximum height Rz of the unevenness is not less than 5 μm and not more than 50 μm.

Configuration 5

The coating head according to any one of Configurations 1 to 4, wherein

the plurality of elastic members includes a spring.

Configuration 6

The coating head according to any one of Configurations 1 to 5, wherein

the position controller includes an actuator.

Configuration 7

The coating head according to any one of Configurations 1 to 6, wherein

at least a portion of the one of the plurality of first recesses is curved.

Configuration 8

The coating head according to any one of Configurations 1 to 7, wherein

the one of the plurality of nozzles includes an end surface dispensing the liquid, and

an angle between the end surface and an extension direction in which the one of the plurality of nozzles extends is not less than 80 degrees and not more than 100 degrees.

Configuration 9

The coating head according to any one of Configurations 1 to 8, wherein

the one of the plurality of nozzles includes a nozzle portion and a base part,

the nozzle portion is detachable from the base part,

the liquid is supplied to the base part, and

the liquid is dispensed from the nozzle portion.

Configuration 10

The coating head according to Configuration 9, wherein

the nozzle portion is between the one of the plurality of first recesses and the one of the plurality of third members, and

the base part is not between the one of the plurality of first recesses and the one of the plurality of third members.

Configuration 11

The coating head according to any one of Configurations 1 to 10, wherein

the coating bar is configured to form a meniscus of the liquid between the coating bar and the coating member.

Configuration 12

The coating head according to any one of Configurations 1 to 11, wherein

the one of the plurality of third members includes a second recess, and

the at least a portion of the one of the plurality of nozzles is between the second recess and the one of the plurality of first recesses.

Configuration 13

The coating head according to any one of Configurations 1 to 12, wherein

the position controller includes:

a first holder holding the coating bar; and

a second holder holding the plurality of nozzles,

at least one of the first holder or the second holder is configured to apply stress to at least one of the coating bar or the plurality of nozzles, and

the stress has at least one of an orientation from the coating bar toward the plurality of nozzles or an orientation from the plurality of nozzles toward the coating bar.

Configuration 14

The coating head according to Configuration 13, wherein

at least one of the plurality of nozzles reversibly bends according to the stress.

Configuration 15

A coating apparatus, comprising:

the coating head according to any one of Configurations 1 to 14;

a supplier supplying the liquid to the plurality of nozzles; and

a coating member holder holding the coating member and moving the coating member relative to the coating head.

Configuration 16

The coating apparatus according to Configuration 15, wherein

the coating member includes a roll-shaped film, and

the coating member holder includes:

a first holding mechanism holding a first portion of the roll-shaped film; and

a second holding mechanism holding a second portion of the roll-shaped film.

Configuration 17

The coating apparatus according to Configuration 15 or 16, wherein

the supplier includes a plurality of pumps, and

a number of the plurality of nozzles is an integer multiple of the plurality of pumps.

Configuration 18

The coating apparatus according to any one of Configurations 15 to 17, wherein

a position of at least a portion of the coating member holder is higher than a position of the supplier.

Configuration 19

The coating apparatus according to any one of Configurations 15 to 18, further comprising:

a liquid sensor detecting a supply rate of the liquid to the plurality of nozzles; and

a supply controller controlling the supplier based on the supply rate detected by the liquid sensor.

Configuration 20

A coating method, comprising:

coating the liquid onto the coating member by using the coating head according to any one of Configurations 1 to 14.

According to embodiments, a coating head, a coating apparatus, and a coating method are provided in which a uniform coated film can be formed.

Hereinabove, embodiments of the invention are described with reference to specific examples. However, the invention is not limited to these specific examples. One skilled in the art may similarly practice the invention by appropriately selecting specific configurations of components such as, for example, the coating bar, the member, the nozzle, the controller, etc., included in the coating head from known art; and such practice is within the scope of the invention to the extent that similar effects can be obtained.

Furthermore, combinations of any two or more components of the specific examples within the extent of technical feasibility are within the scope of the invention to the extent that the purport of the invention is included.

Furthermore, all coating heads, coating apparatuses, and coating methods practicable by an appropriate design modification by one skilled in the art based on the coating head, the coating apparatus, and the coating method described above as embodiments of the invention also are within the scope of the invention to the extent that the purport of the invention is included.

Moreover, various modifications and alterations within the spirit of the invention will be readily apparent to those skilled in the art; and all such modifications and alterations should be seen as being within the scope of the invention.

While certain embodiments of the inventions have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. These novel embodiments may be embodied in a variety of other forms; and various omissions, substitutions, and changes may be made without departing from the spirit of the inventions. Such embodiments and their modifications are within the scope and spirit of the inventions and are included in the inventions described in the claims and their equivalents.

What is claimed is:

1. A coating head, comprising:

a coating bar configured to face a coating member;

a plurality of nozzles configured to supply a liquid toward the coating bar;

a first member including a plurality of first recesses,

a plurality of second members;

a plurality of third members, at least a portion of one of the nozzles being between one of the first recesses and one of the third members, the at least a portion of the one of the nozzles and the one of the third members being fixed to the first member by one of the second members;

a plurality of elastic members, one of the elastic members being located in at least one of a first position, a second position, or a third position, the first position being between the one of the third members and the one of the second members, the second position being between the at least a portion of the one of the first recesses and the one of the nozzles, the third position being between the at least a portion of the one of the nozzles and the one of the third members; and

a position controller controlling a relative position between the coating bar and the nozzles.

2. The head according to claim **1**, wherein

the nozzles contact the coating bar.

3. The head according to claim **1**, wherein

the one of the first recesses extends along a direction in which the at least a portion of the one of the nozzles extends.

4. The head according to claim 1, wherein
a surface of the coating bar includes an unevenness, and
a maximum height Rz of the unevenness is not less than 5 μm and not more than 50 μm.

5. The head according to claim 1, wherein
the elastic members include a spring.

6. The head according to claim 1, wherein
the position controller includes an actuator.

7. The head according to claim 1, wherein
at least a portion of the one of the first recesses is curved.

8. The head according to claim 1, wherein
the one of the nozzles includes an end surface dispensing the liquid, and
an angle between the end surface and an extension direction of the one of the nozzles in which the one of the nozzles extends is not less than 80 degrees and not more than 100 degrees.

9. The head according to claim 1, wherein
the one of the nozzles includes a nozzle portion and a base part,
the nozzle portion is detachable from the base part,
the liquid is supplied to the base part, and
the liquid is dispensed from the nozzle portion.

10. The head according to claim 9, wherein
the nozzle portion is between the one of the first recesses and the one of the third members, and
the base part is not between the one of the first recesses and the one of the third members.

11. The head according to claim 1, wherein
the coating bar is configured to form a meniscus of the liquid between the coating bar and the coating member.

12. The head according to claim 1, wherein
the one of the third members includes a second recess, and
the at least a portion of the one of the nozzles is between the second recess and the one of the first recesses.

13. The head according to claim 1, wherein
the position controller includes:
a first holder holding the coating bar; and
a second holder holding the nozzles,
at least one of the first holder or the second holder is configured to apply stress to at least one of the coating bar or the nozzles, and
the stress has at least one of an orientation from the coating bar toward the nozzles or an orientation from the nozzles toward the coating bar.

14. The head according to claim 13, wherein
at least one of the nozzles reversibly bends according to the stress.

15. A coating apparatus, comprising:
a coating head including a coating bar configured to face a coating member, a plurality of nozzles configured to supply a liquid toward the coating bar, a first member including a plurality of first recesses, a plurality of second members, a plurality of third members, at least a portion of one of the nozzles being between one of the first recesses and one of the third members, the at least a portion of the one of the nozzles and the one of the third members being fixed to the first member by one of the second members, a plurality of elastic members, one of the elastic members being located in at least one of a first position, a second position, or a third position, the first position being between the one of the third members and the one of the second members, the second position being between the at least a portion of the one of the first recesses and the one of the nozzles, the third position being between the at least a portion of the one of the nozzles and the one of the third members, and a position controller controlling a relative position between the coating bar and the nozzles;
a supplier supplying the liquid to the nozzles; and
a coating member holder holding the coating member and moving the coating member relative to the coating head.

16. The apparatus according to claim 15, wherein
the coating member includes a roll-shaped film, and
the coating member holder includes:
a first holding mechanism holding a first portion of the roll-shaped film; and
a second holding mechanism holding a second portion of the roll-shaped film.

17. The apparatus according to claim 15, wherein
the supplier includes a plurality of pumps, and
a number of the nozzles is an integer multiple of the pumps.

18. The apparatus according to claim 15, wherein
a position of at least a portion of the coating member holder is higher than a position of the supplier.

19. The apparatus according to claim 15, further comprising:
a liquid sensor detecting a supply rate of the liquid to the plurality of nozzles; and
a supply controller controlling the supplier based on the supply rate detected by the liquid sensor.

20. A coating method, comprising:
coating a liquid onto a coating member by using a coating head, the coating head including a coating bar configured to face the coating member, a plurality of nozzles configured to supply the liquid toward the coating bar, first member including a plurality of first recesses, a plurality of second members, a plurality of third members, at least a portion of one of the nozzles being between one of the first recesses and one of the third members, the at least a portion of the one of the nozzles and the one of the third members being fixed to the first member by one of the second members, a plurality of elastic members, one of the elastic met bergs being located in at least one of a first position, a second position, or a third position, the first position being between the one of the third members and the one of the second members, the second position being between the at least a portion of the one of the first recesses and the one of the nozzles, the third position being between the at least a portion of the one of the nozzles and the one of the third members, and a position controller controlling a relative position between the coating bar and the nozzles.

* * * * *